Journal of Photochemistry & Photobiology, B: Biology 158 (2016) 228–234

Contents lists available at ScienceDirect

Journal of Photochemistry & Photobiology, B: Biology

journal homepage: www.elsevier.com/locate/jphotobiol

Effects of enhanced UV-B radiation on the nutritional and active ingredient contents during the floral development of medicinal chrysanthemum

Chun Hui Ma, Jian Zhou Chu, Xiao Fei Shi, Cun Qi Liu, Xiao Qin Yao *

The College of Life Sciences, Hebei University, Baoding 071002, China

ARTICLE INFO

Article history:
Received 14 October 2015
Accepted 22 February 2016
Available online 27 February 2016

Keywords:
Chlorogenic acid
Chrysanthemum
Postharvest flower
UV-B radiation

ABSTRACT

The paper mainly studied the effects of enhanced UV-B radiation on the nutritional and active ingredient contents during the floral development of medicinal chrysanthemum. The experiment included two levels of UV-B radiation (0 and 400 μW cm^{-2}). The contents of hydrogen peroxide (H_2O_2), anthocyanin, UV-B absorbing compounds, total chlorophyll and carotenoids, and the activities of phenylalanine ammonia lyase enzyme (PAL) and cinnamic acid-4-hydroxylase enzyme (C4H) in flowers significantly decreased with the floral development. However, the contents of soluble sugar, amino acid and total vitamin C in flowers significantly increased with the floral development. The contents of flavonoid and chlorogenic acid were significantly different in the four stages of floral development, and their highest contents were found in the bud stage (stage 2). In the four stages of floral development, enhanced UV-B radiation significantly increased the contents of H_2O_2, UV-B absorbing compounds, chlorophyll, carotenoids, soluble sugar, amino acid, vitamin C, flavonoid and chlorogenic acid, and the activities of PLA and C4H in flowers. The results indicated that the highest contents of active and nutrient ingredients in flowers were found not to be in the same developmental stages of flowers. Comprehensive analysis revealed that the best harvest stage of chrysanthemum flowers was between the bud stage and the young flower stage (stage 2 and stage 3), which could simultaneously gain the higher contents of active and nutritional ingredients in flowers.

1. Introduction

The reduction of stratospheric ozone has become a global problem, which results in the increase of solar UV-B radiation on the earth's surface. Enhanced UV-B radiation has already got comprehensive attention among the governments and scientists [1]. In general, enhanced UV-B radiation can negatively affect growth, physiology and productivity of plants [2–6]. In recent years, however, some interesting results about UV-B beneficial effects on secondary metabolism processes in plants have been found [7–8]. Most of the medically active ingredients in medicinal plants are secondary metabolites. Therefore, it is considered of interest to determine if active ingredient contents in medicinal plants can be improved by enhanced UV-B radiation which is a simple and environmental-friendly method.

At present, a few studies have reported UV-B effects on medicinal plants [7,9–12]. Previous results indicated that enhanced UV-B radiation could induce secondary metabolism processes, and increase active ingredient contents in medicinal plants. However, enhanced UV-B radiation in previous experiments was applied during growth stages of plants, which was difficult to manage (especially for regions with no reliable electricity source) and required a large investment in production. Therefore, further studies to explore methods for improving active ingredient contents by UV-B radiation were deemed necessary.

In order to better applying UV-B radiation technology on medicinal plants, some scientists began to study the effects of UV-B radiation on isolated organs of medical plants. Schreiner et al. reported the effects of short-term and moderate UV-B radiation on active ingredients in different postharvest organs of nasturtium (*Tropaeolum maius* L.) [13]. The results showed that enhanced UV-B radiation increased the glucotropaeolin concentration up to 6-fold in comparison to the control plants. Sun et al. found that UV-B radiation increased the contents of secondary metabolites in postharvest leaves of ginkgo (*Ginkgo biloba* L.) [14]. In previous experiments, we also found that moderate UV-B radiation could affect biochemical traits in isolated flowers of medicinal chrysanthemum [15]. To our knowledge, there have been limited efforts to know effects of enhanced UV-B radiation on the contents of nutritional and active ingredients during the floral development of medicinal chrysanthemum. In addition, the scientists are just beginning to study UV-B effects on isolated organs of medicinal plants. So, more works should be done for better evaluation of the application of UV-B radiation in medicinal plants.

Medicinal chrysanthemum (*Chrysanthemum morifolium* Ramat) is one of important export medicines in China. Medicinal chrysanthemum flowers are used in traditional medicine where they play an important role in improving liver function, decreasing inflammation, improving

* Corresponding author.
E-mail address: yaoxiao301@126.com (X.Q. Yao).

http://dx.doi.org/10.1016/j.jphotobiol.2016.02.019
1011-1344/

eyesight and serving other anti-inflammatory detoxification roles [10]. Flavonoids and chlorogenic acid are main active ingredients in chrysanthemum flowers, and free amino acid, vitamin C and soluble sugar are main nutritional ingredients in flowers. The paper mainly studied the effects of enhanced UV-B radiation on biochemical traits and quality during the floral development of medicinal chrysanthemum, in order to finding the stage which is more sensitive to enhanced UV-B, so as to determining the best harvest stage according to the contents of nutritional and active ingredients in flowers. This will be helpful for further research about the application of UV-B radiation on medicinal plants.

2. Materials and Methods

2.1. Plant Material and Experimental Design

The research was conducted at Hebei University, Baoding, China. The seedlings of Qi chrysanthemum were obtained from Anguo Chinese herbal medicine planting base, Hebei province, China. The seedlings of the same size were selected based on plant height, and planted into the farmland. Routine field managements were conducted during growth stages of chrysanthemum. Fresh flowers were harvested, and divided into four stages according to floral development (Plate 1): young bud stage, ends of sepals completely separated from each other while ray florets being not opened yet (bud diameter 0.8–1.2 cm); bud stage, ray florets being opened while tubular florets being not opened yet (bud diameter 1.8–2.2 cm); young flower stage, ray florets being opened while tubular florets being opened 20%–40% (faceplate diameter 2.8–3.2 cm); flower stage, ray florets being opened while tubular florets being opened 50–70% (faceplate diameter 3.6–4.0 cm).

The harvested flowers were immediately treated with UV-B radiation for 60 min. The experiment included two levels of UV-B radiation: (1) 0 μW cm^{-2} (CK), and (2) 400 μW cm^{-2} (UV-B). After UV-B radiation, the flowers were put into the incubator (25 °C, 80% humidity) for 6 h. Each treatment had five replications.

2.2. UV-B Treatments

Enhanced UV-B radiation was produced by UV-B fluorescent lamps (40 W, 305 nm, Beijing Electronic Resource Institute, Beijing, China) mounted in metal frames. In the control incubator, UV-B from the lamps was excluded by wrapping the tubes with 0.125 mm polyester film (Chenguang Research Institute of Chemical Industry, China), which transmits UV-A.

2.3. Hydrogen Peroxide and Malondialdehyde Content

Hydrogen peroxide (H_2O_2) content was determined as described by Prochazkova et al. [11]. The 0.5 g fresh sample was ground with 5 mL cooled acetone in a cold room (10 °C). Mixture was filtered with filter paper followed by the addition of 2 mL 5% titanium sulfate and 5 mL ammonium solution to precipitate the titanium–hydrogen peroxide complex. The reaction mixture was centrifuged at 10 000 $\times g$ for 10 min. The precipitate was dissolved in 5 mL of 2 mol L^{-1} H_2SO_4 and then recentrifuged. The absorbance of supernatant was measured at 415 nm by spectrophotometer.

The degree of lipid peroxidation in flower tissue was assessed by malondialdehyde (MDA) content. MDA content was measured as described by Feng et al. with minor modification [12]. The 0.5 g fresh sample was extracted with 6 mL of 10% (w/v) trichloroacetic acid (TCA). The homogenate was centrifuged at 4000 $\times g$ for 10 min. 1 mL supernatant and 1 mL TCA were added to 2 mL of 20% TBA solution containing 0.6% (w/v) thiobarbituric acid. The mixture was kept in boiling water bath for 15 min and then quickly cooled on ice. The absorbance of supernatant was measured at 532 nm and 600 nm by spectrophotometer, respectively. The value for non-specific absorption at 600 nm was

Plate 1. Floral development in Qi Chrysanthemum (from the right to the left: Stage 1, stage 2, stage 3 and stage 4).